A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models

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- Global models parameterize the effects of processes that occur on scales near or below the horizontal grid spacing, including turbulence, convection, and associated cloud and radiation processes.

- Current global forecast models use grid spacings of a few tens of kilometers; in the next few years the mesh size is expected to be less than ten kilometers.

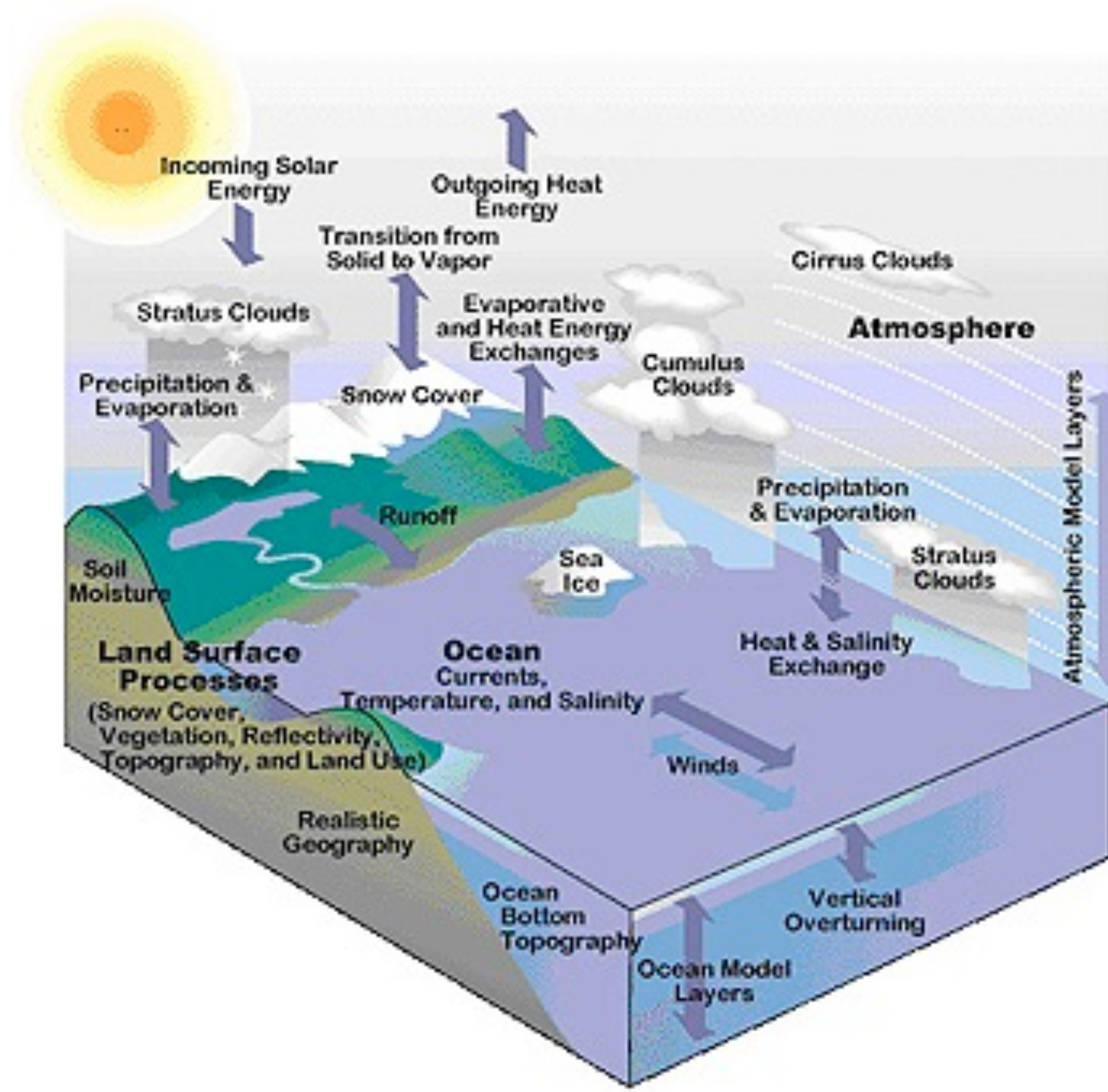
- Conventional parameterizations of deep convection rely on assumptions that are fundamentally inconsistent with such high-resolution models.

- Smaller clouds such as shallow cumuli, however, will not be even partially resolved in the foreseeable future.

- Developing parameterizations that work well across a range of parameterized and explicit phenomena is a significant challenge.

Project Summary

- The goal is to unify the representation of turbulence and SGS cloud processes and to unify the representation of SGS deep convective precipitation and grid-scale precipitation as the horizontal resolution decreases.



PDF-based SGS turbulence

- We will install a PDF-based SGS turbulence and cloudiness scheme that will replace the boundary layer turbulence scheme, the shallow convection scheme, and the cloud fraction schemes in the GFS and CFS.

Simplified Higher-Order Closure (SHOC)

- SHOC integrates several existing components:
  - A **prognostic SGS TKE** equation.
  - The **assumed PDF** method of Golaz et al. (2002): joint double-Gaussian PFDs of vertical velocity, liquid water potential temperature, and total water.
  - The **diagnostic second-moment closure** of Redelsperger and Sommeria (1986).
  - The **diagnostic closure for <w'w'w'>** by Canuto et al. (2001).
  - A **turbulence length scale** related to the square root of SGS TKE (Teixeira and Cheinet 2004) and eddy length scales.
- We implemented SHOC in a CRM and tested it extensively against **LES** (Bogenschutz and Krueger 2013).
- Bogenschutz also implemented SHOC in a GCM that uses the Multiscale Modeling Framework (MMF) which embeds a 2D CRM in every GCM grid column.

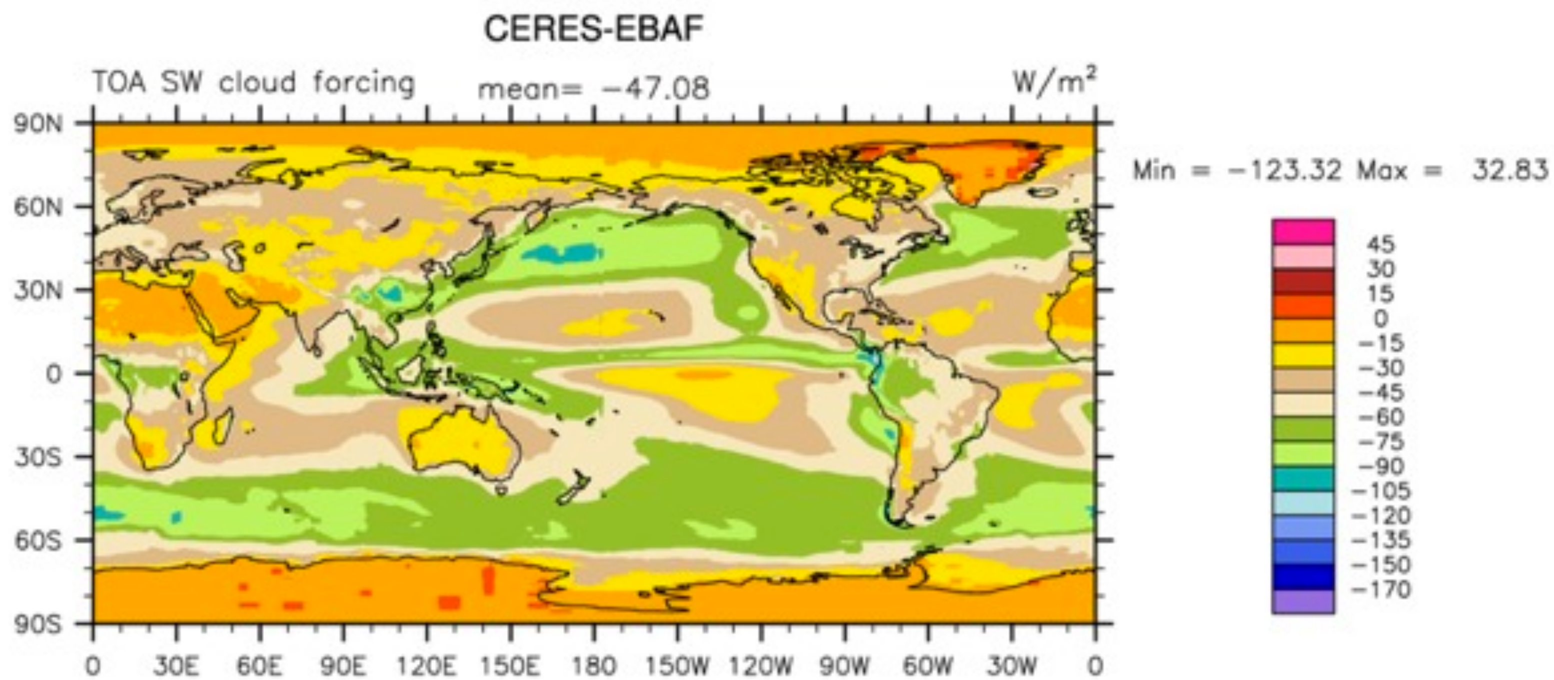
SP-CAM-SHOC Simulations Performed

- **AMIP simulations:** 2-degree resolution for the host model (CAM)
- **For SP-CAM and SP-CAM-SHOC a series of AMIP simulations were performed** in variety of domain sizes for the embedded CRM:
  - Standard configuration: 10 years
  - Small 3D configuration: 10 years
  - Large 3D configuration: 1 year
- **Preliminary 25-year coupled simulation performed with SP-CAM-SHOC** with small 3D configuration.

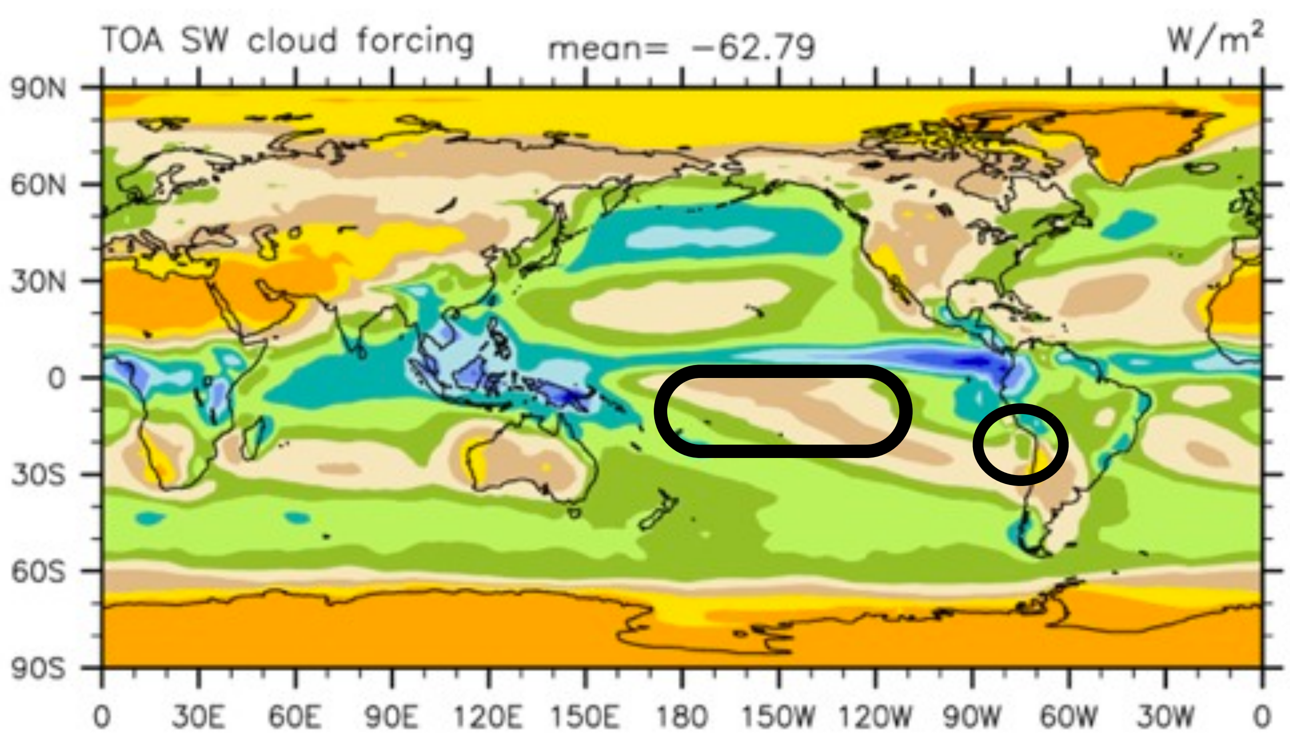
Shortwave Cloud Effects

SP-CAM and SP-CAM-SHOC results shown use small 3D CRM for embedded CRM.

Other configurations produce similar results.

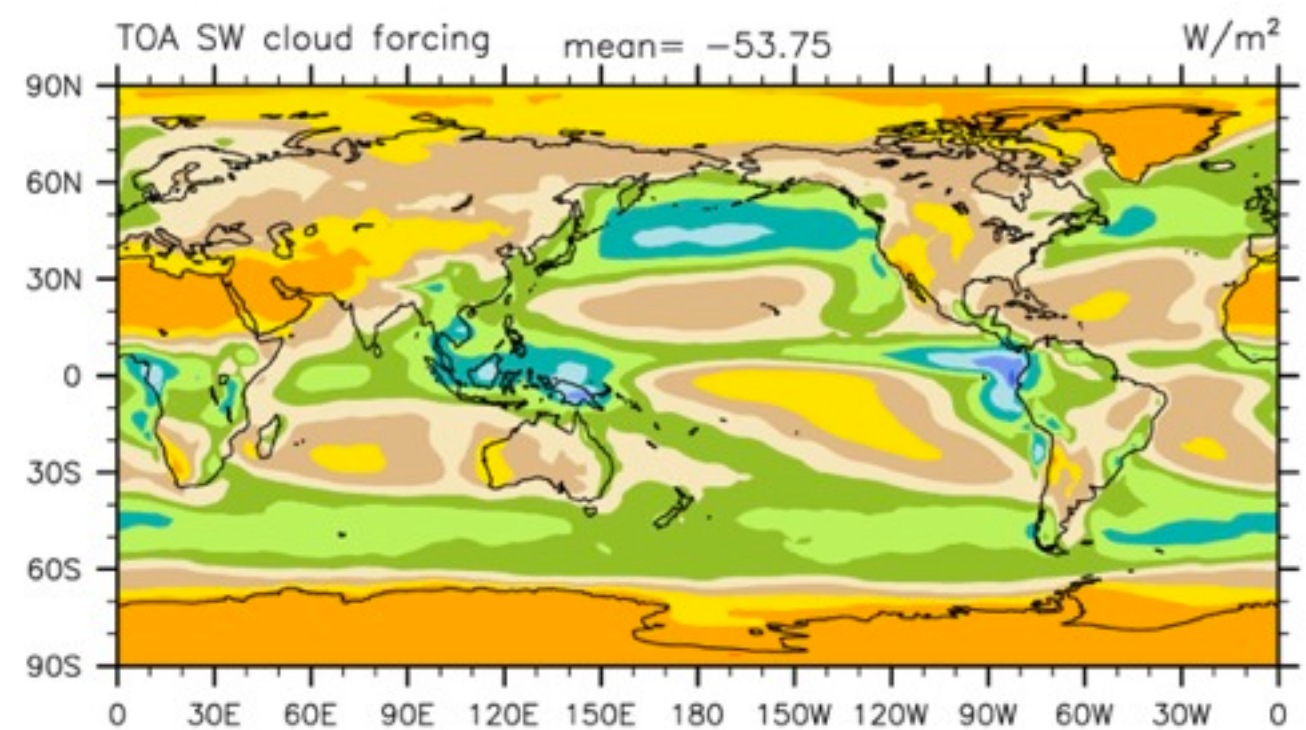


SP-CAM



RMSE: 22.5 W/m2

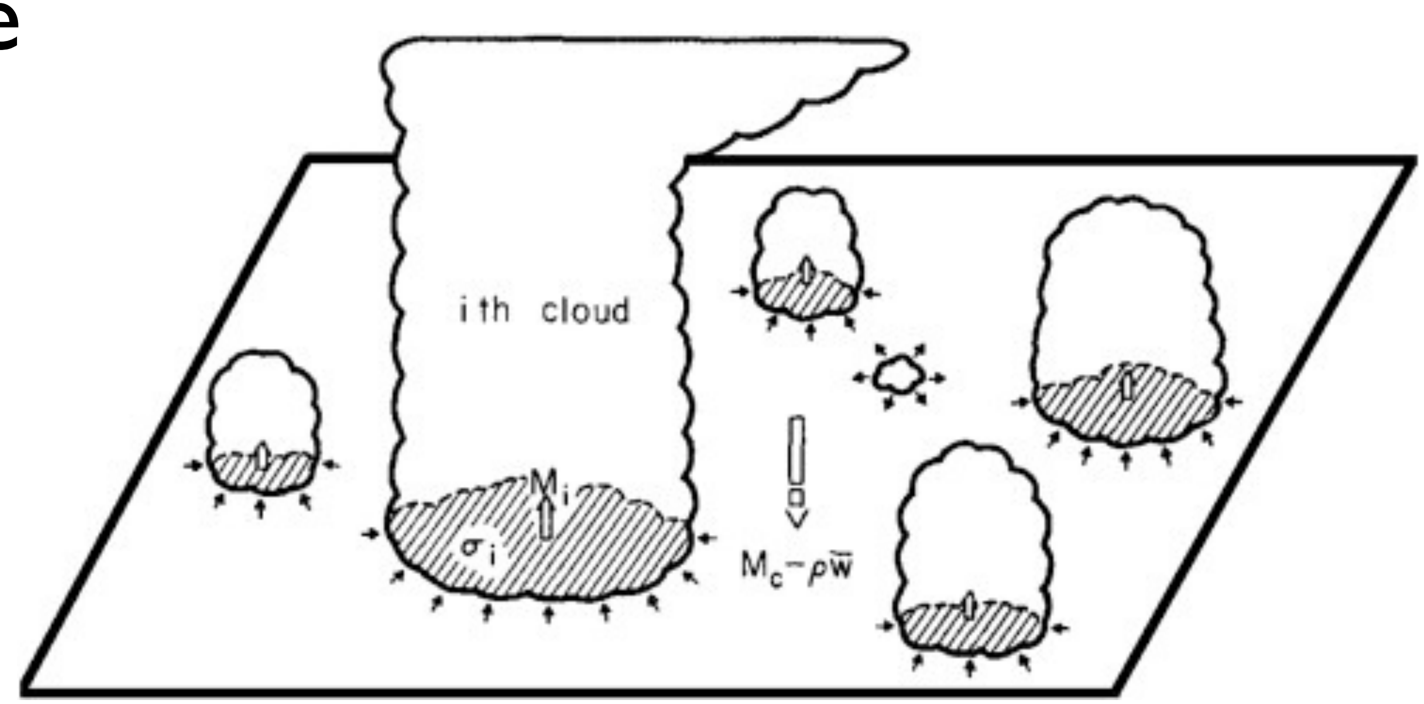
SP-CAM-SHOC



RMSE: 14.7 W/m2

Unified Cumulus Parameterization

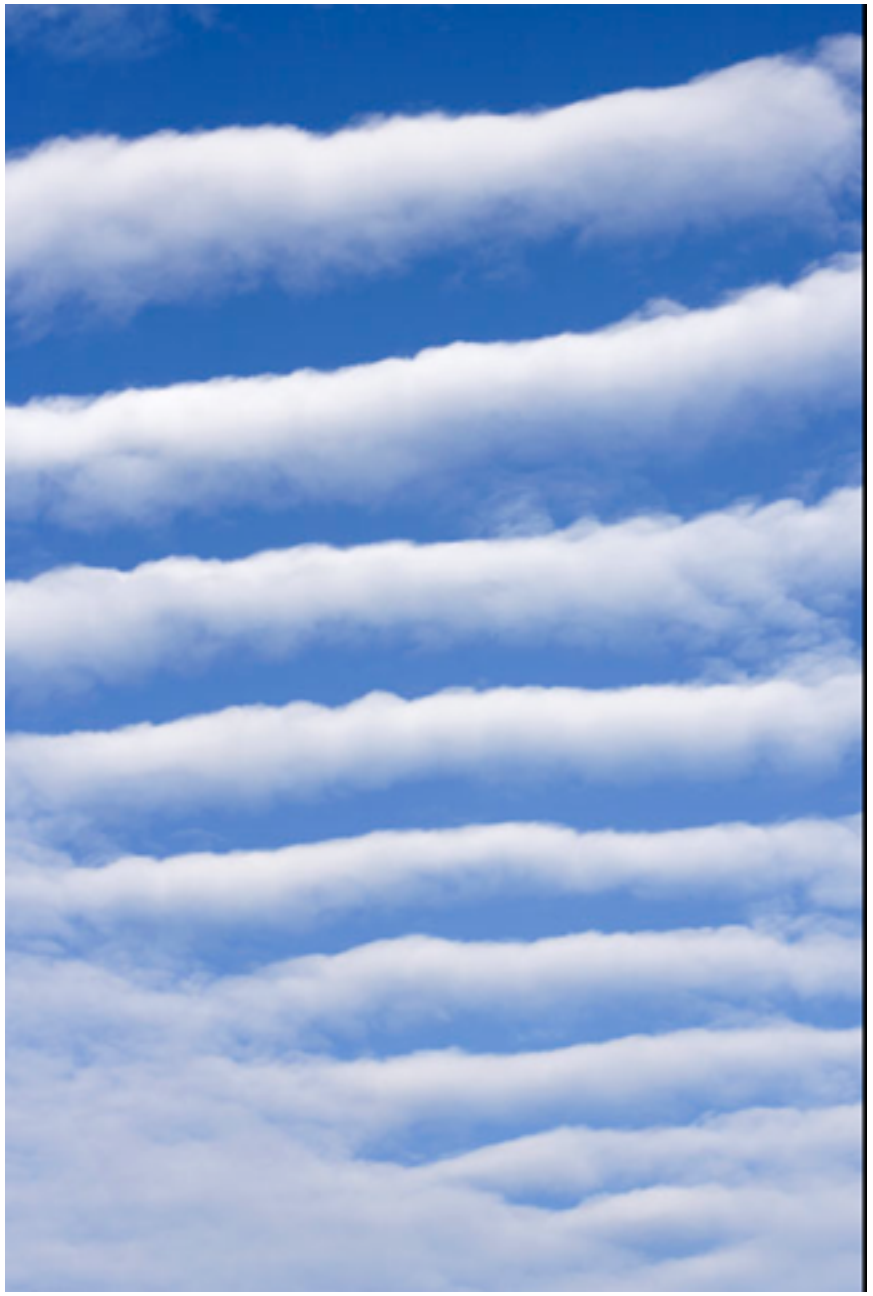
- We hope to improve the treatment of deep convection by introducing a unified parameterization that scales continuously between simulating individual clouds on fine grids, and the behavior of a conventional parameterization of deep convection on coarse grids.



Plan

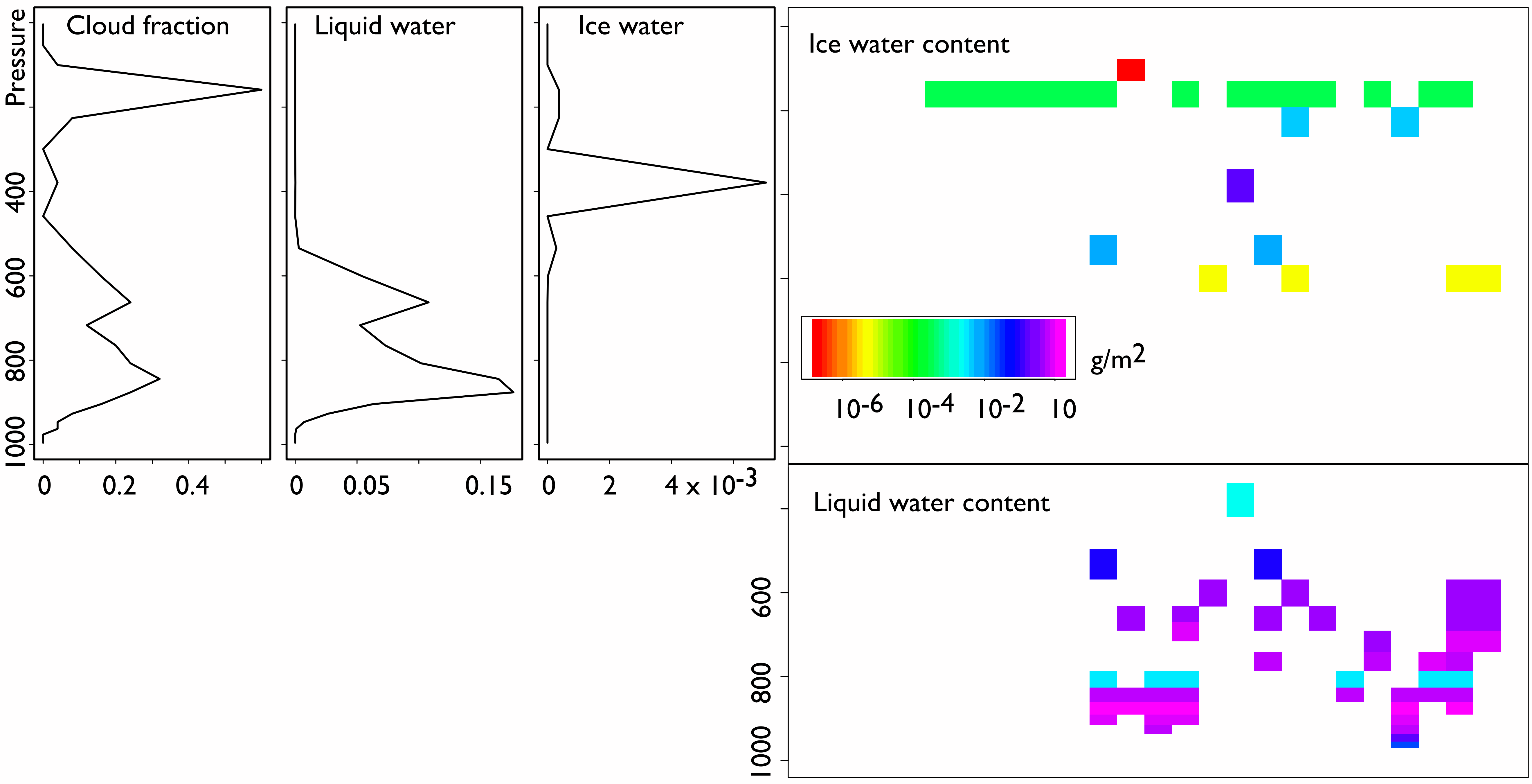
- The conventional parameterization of Chikira and Sugiyama (2010) will be used:
  - Multiple cloud types
  - Predicted vertical velocity
  - Prognostic closure

- Chikira's parameterization will be modified following the approach described in Arakawa and Wu (2013) and Wu and Arakawa (2014).

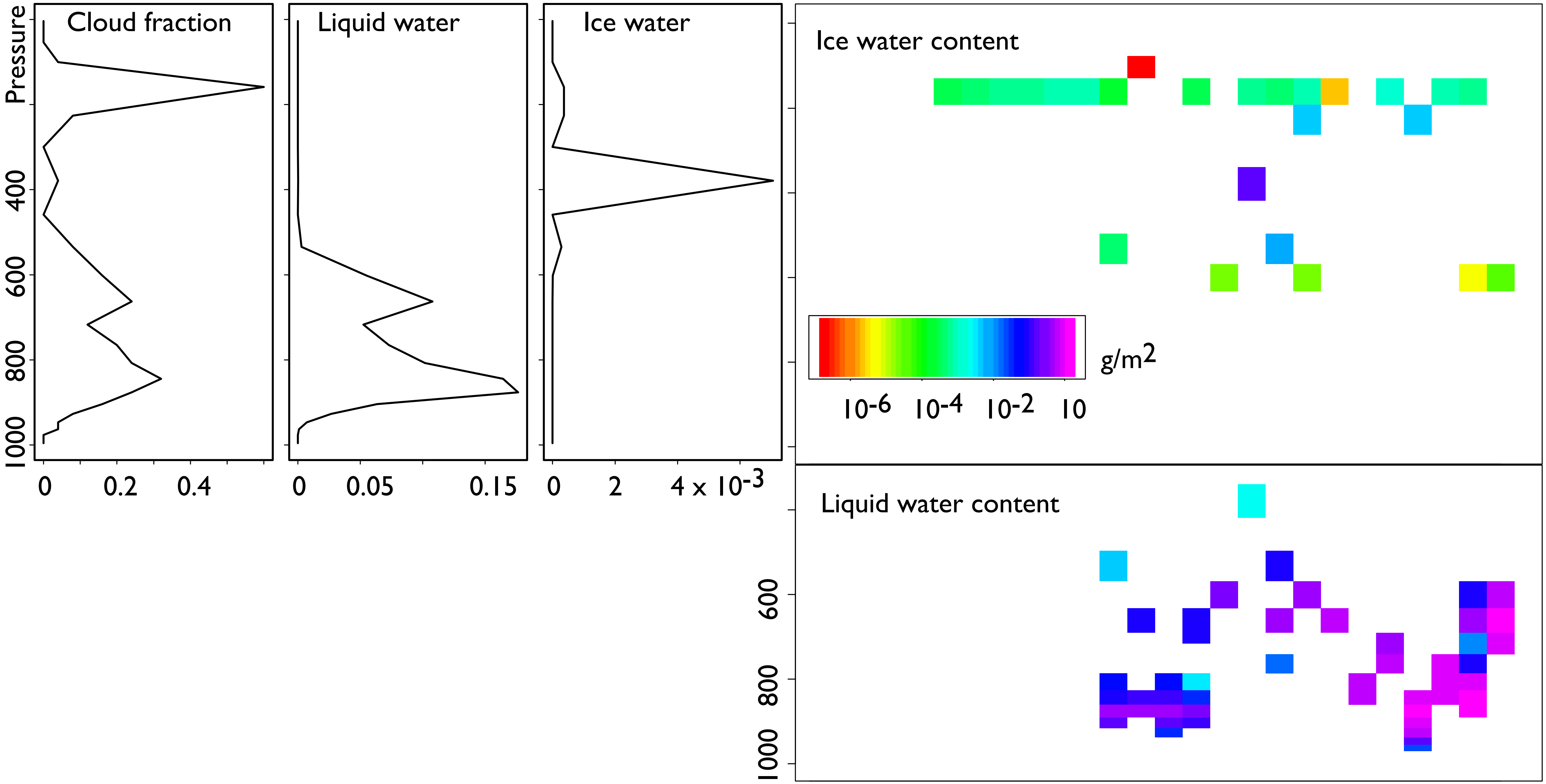


Interactions of Clouds, Radiation, and Microphysics

- We hope to improve the representation of the interactions of clouds, radiation, and microphysics in the GFS/CFS by using the additional information provided by the PDF-based SGS cloud scheme.



uses only the mean value of liquid or ice concentration at each level



uses a distribution of liquid or ice concentration at each level obtained from SHOC

Treating cloud variability in radiation

Radiation in the GFS uses "RRTMG" which in turn treats fractional cloudiness with McICA (Monte Carlo Independent Column Approximation).

McICA approximates broadband radiation calculations over a distribution of cloud properties with a single broadband calculation over a discrete set of random samples.

The variability in cloud properties predicted by SHOC can be included equally accurately at near-zero expense.

Implementation Plan

- **Implement the new physics modules in NCEP SCM**

  - Test, tune and evaluate the physics modules using ARM data

- **Implement in the NCEP GSM**

  - Test, tune and evaluate the performance of these new physics using the standard procedure used at EMC (including cycled data assimilation/forecast tests)

- **Implement in the NCEP Coupled Model**

  - Test, tune and evaluate for climate applications – seasonal prediction and long coupled climate runs